Accepted Manuscript

Title: Relationship of sleep quality, baseline weight status and weight loss responsiveness in obese adolescents in an immersion treatment program.

Author: Cecelia R. Valrie, Kayzandra Bond, Lesley D. Lutes, Marissa Carraway, David N. Collier

PII: S1389-9457(14)00480-8
DOI: http://dx.doi.org/doi: 10.1016/j.sleep.2014.11.007
Reference: SLEEP 2603

To appear in: *Sleep Medicine*

Received date: 22-10-2014
Revised date: 20-11-2014
Accepted date: 23-11-2014

Please cite this article as: Cecelia R. Valrie, Kayzandra Bond, Lesley D. Lutes, Marissa Carraway, David N. Collier, Relationship of sleep quality, baseline weight status and weight loss responsiveness in obese adolescents in an immersion treatment program., *Sleep Medicine* (2014), http://dx.doi.org/doi: 10.1016/j.sleep.2014.11.007.

Relationship of Sleep Quality, Baseline Weight Status and Weight Loss Responsiveness in Obese Adolescents in an Immersion Treatment Program.

Cecelia R. Valrie, PhD[a], Kayzandra Bond, MA[b], Lesley D. Lutes, PhD[c], Marissa Carraway, PhD[d], David N. Collier, MD, PhD[e]

[a]Department of Psychology, East Carolina University, Greenville, NC 27858, United States; Email: valriec@ecu.edu

[b]Department of Psychology, East Carolina University, Greenville, NC 27858, United States; Email: exumk10@students.ecu.edu

[c]Department of Psychology, East Carolina University, Greenville, NC 27858, United States; Email: lutesl@ecu.edu

[d]Department of Psychology, East Carolina University, Greenville, NC 27858, United States; Email: marissacarraway@alumni.ecu.edu

[e]Department of Pediatrics, Brody School of Medicine, East Carolina University, Greenville, NC 27834, United States

Email: collierd@ecu.edu

* Correspondence to:

Cecelia R. Valrie, PhD, Associate Professor, Dept of Psychology, 104 Rawl Building, Greenville, NC 27858, Email: valriec@ecu.edu

Phone: 252-328-1381, Fax: 252-328-6283

Highlights

- Examined relations between sleep and weight status of obese adolescents
- Investigated effect of sleep on weight-loss responsiveness in obese adolescents
- Disrupted sleep related to higher pre-treatment zBMIs and waist circumferences
- Adolescent sleep deprivation related to lower responsive to weight-loss treatment
- Immersion treatment related to modest improvements in sleep

Abstract

Objective: To investigate the effect of baseline sleep on baseline weight status and weight-loss responsiveness in obese adolescents enrolled in an immersion treatment (IT) program.

Methods: Twenty-five obese adolescents who participated in a 19-day summer camp-based IT program completed pre-intervention subjective measures of sleep duration and quality, and pre- and post-intervention BMI z-scores (zBMI) and waist circumference (WC) assessments. Objective measures of sleep were obtained by actigraphy for a random subset of six participants for one week prior to and after camp.

Results: Participant's zBMIs and WCs were significantly reduced pre- to post-intervention (M_{diff} zBMI=0.7±09, t=4.1, p<.01 and M_{diff} WC=2.57±3.51, t=3.7, p<.01). Shorter weekday sleep durations and more sleep debt (i.e., participants average weekend sleep duration minus their average weekday sleep duration) were related to higher pre-intervention WCs (r=-.54, p=.01 and r=-.56, p=.01), and lower subjective sleep quality was related to higher pre-intervention zBMIs (r=-.49, p=.02). Also, longer weekend sleep durations and more sleep debt were related to smaller reductions in pre- to post-intervention zBMIs (r=-.47, p=.04 and r=-.51, p=.03). For the subgroup of adolescents who wore actigraphs pre- and post-intervention, participants increased their sleep durations (d=-.25), and reduced their sleep latencies (d=.52), zBMIs (d=.31) and WCs (d=.20).

Conclusions: These results provide further evidence linking poor sleep patterns and obesity in adolescence. They also suggest that sleep patterns may impact the effectiveness of pediatric

obesity interventions and that IT programs may improve sleep in obese adolescents. Overall, they provide support for addressing sleep problems as part of obesity interventions.

Keywords: obesity, immersion treatment, sleep, adolescents, pediatrics, intervention

1. Introduction

Approximately one in five adolescents in the US is obese,[1] and obesity during adolescence is associated with a range of problems,[2] including increased risk of obesity in adulthood,[3] cardiovascular disease, and early mortality.[2] Interventions that promote improvements in dietary intake, increased physical activity, and the development of behavioral techniques for managing weight are the most common treatments used to address pediatric obesity.[4] These treatments produce positive, but only small to moderate improvements in weight status and weight-related health outcomes; thus, there is a need to identify additional targets for intervention that may improve treatment outcomes.

Short sleep duration is a recognized risk factor for childhood obesity.[5-6] Children with shorter sleep durations have a 58% increased risk for obesity while each 1 hour increase in sleep duration results in a 9% decrease in obesity risk. Children who are obese are also at higher risk of disrupted sleep patterns.[7-8] A study of obese preschoolers enrolled in a weight loss program found that post-treatment sleep duration significantly predicted lower post-treatment BMI z-scores (zBMI).[9] Furthermore children who either maintained longer sleep durations or increased their sleep durations during the treatment had lower post-treatment zBMIs. However no published studies to date have assessed the possible influences of pre-treatment sleep patterns on weight loss treatment effectiveness in older children and adolescents.

The present pilot study examined the relationship between pre-treatment sleep and treatment outcomes in obese adolescents who participated in an immersion treatment (IT) program. We hypothesized that shorter sleep durations and more disrupted sleep patterns pre-treatment would be associated with higher zBMI scores and waist circumferences (WCs) pre-

and post-treatment, and decreased efficacy of the treatment as evidenced by smaller reductions in zBMIs and WCs pre- to post-treatment.

2. Methods

2.1. Participants

Participants were drawn from 34 adolescents aged 12-16 years with BMIs of ≥ 95th percentile for age and sex who had participated in a 19 day camp-based IT program during the summer of 2010.[10] The current study used data from 25 adolescents aged 12-16 years (mean=14 years, SD=1.5 years) with an initial mean BMI=40.6kg/m^2 (SD=8.1kg/m^2, range=26.6-56.7kg/m^2), initial mean zBMI=2.48 (SD=0.34, range=1.82-3.19), and an initial mean WC=114.2cm (SD=12.5cm, range=91.0-134.0cm). The majority were female (68%) and African American (56%). Exclusion criteria for the current study included not completing camp (n=4), being diagnosed with sleep apnea, or taking sleep medication (n=5). The current sample did not significantly differ from the larger treatment sample.

Nine adolescents chosen at random were asked to wear sleep actigraphs the week before and after camp to collect objective sleep data. Data from 3 participants were excluded because they had less than 4 days of actigraph data pre or post-intervention. The remaining 6 adolescents were younger (mean=13 years, SD=0.8 years) than the adolescents from the larger treatment sample ($t = 4.92$, $p = .04$), but did not differ on other variables. The University's Institutional Review Board approved this study. Informed written consent and assent was obtained from parents and adolescents, respectively.

2.2 Procedure

The camp-based IT program was designed to promote both long-term healthy lifestyle changes and significant short-term improvements in weight status.[10] The main elements of the

intervention comprised nutrition and physical activity education, group and individual cognitive behavioral therapy, and an integrated nutrition and physical activity program designed to induce 1,000–1,200 kcal daily net negative energy balance. Quiet time in cabins began at 9:00 p.m., lights were turned off at 10:00 p.m., and reveille was at 7:00 a.m. Prior to camp, parents reported on adolescents' age, sex, ethnicity, and weekday (Monday-Friday) and weekend (Saturday-Sunday) sleep durations during the past month, and adolescents completed questionnaires on their behavioral sleep patterns. On the first and last days of camp, adolescents were weighed (kg), and height (cm) and waist circumference (cm) were measured following standard anthropometric procedures. BMIs were calculated and transformed into age- and sex-adjusted zBMIs.[11] A subgroup of adolescents was randomly chosen to wear sleep actrigraph watches for 7 days pre- and post-intervention. The intervention and pre- and post-intervention sleep assessments occurred during the summer.

2.3 Measures

Subjective Behavioral Sleep Measurement

Adolescents' behavioral sleep patterns were assessed using the Adolescent Sleep Wake Scale (ASWS[12]), a 28-item self-report measure that assesses frequency of behavioral sleep problems (e.g., difficulties going to bed, or maintaining sleep) during the previous month. The total behavioral sleep quality score ranges from 1-6, with higher scores indicating better sleep quality. Reported internal consistency for the full scale ASWS was $\alpha = .86$ in a sample of American adolescents.

Objective Sleep Measurement

Octogonal Basic Motionlogger Actigraphs (Ambulatory Monitoring, Inc., NY) monitored movement in 1-minute epochs and data was scored using sleep/wake algorithms developed by

Sadeh and associates.[13] The algorithms have demonstrated reliability and validity when compared to polysomnography. Sleep scores were generated by computing an average score across all available nights. The following sleep variables were computed from the actigraph: (a) total sleep time (TST) – total amount of minutes between sleep onset and waking time, (b) sleep efficiency (SE) – percentage of minutes scored as sleep during TST, (c) activity index (AI) – percentage of TST with evidence of activity, indicative of restless sleep, and (d) sleep latency (SOL) – amount of minutes between bedtime and sleep onset.

3. Results

Consistent with the previous published study,[10] participant's mean zBMIs and WCs were significantly reduced pre- to post-intervention (M_{diff} zBMI=0.7, SD=.09, t=4.1, p<.01 and M_{diff} WC=2.57, SD=3.51, t=3.7, p<.01). Pre-intervention weekday sleep durations ranged from 6.5-11.0 hours per night (mean=8.85 hours, SD=1.33 hours), while weekend sleep durations ranged from 7.0-21.0 hours per night (mean=11.01 hours, SD=3.31 hours). Adolescents slept more on weekend nights than on weekday nights (t=-2.3, p = .03), and their average sleep debt (i.e., participants average weekend sleep duration minus their average weekday sleep duration) =2.08 hours (SD=3.91 hours). Shorter weekday sleep durations were related to higher pre- and post-intervention WCs (r=-.54, p=.01 and r=-.58, p<.01), and more sleep debt was related to higher post-intervention zBMIs (r=-.47, p=.04) and higher pre- and post-intervention WCs (r=-.56, p=.01 and r=-.58, p=.01). The mean sleep quality score was 4.25 (SD=0.97, range=2.07-5.57). Lower sleep quality was related to higher pre- and post-intervention zBMIs (r=-.49, p=.02 and r=-.49, p=.02), and higher post-intervention WCs (r=-.44, p=.03). Also, longer weekend sleep durations and more sleep debt were related to smaller reductions in pre- to post-intervention zBMIs (r=-.47, p=.04 and r=-.51, p=.03, respectively); however, sleep quality was not

significantly related to pre-post intervention changes in zBMIs and WCs. Exploratory analyses examining the data of the subgroup who wore sleep actigraphs found that pre- to post-treatment, participants' zBMIs, WCs, and sleep latencies decreased and their total sleep times increased by about 16 minutes (see Table 1).

4. Discussion

In our sample of obese adolescents, disrupted sleep patterns were related to higher zBMI scores and larger WCs pre- and post-intervention, and longer weekend sleep durations and more sleep debt were related to smaller reductions in zBMIs pre- to post-intervention. These preliminary findings indicate that when adolescents are more sleep deprived, as indicated by the need for more weekend night sleep,[14] behavioral weight loss interventions may become less effective. Results of the current study on adolescents also indicated that the IT intervention, which included a structured sleep schedule that ensured 9 hours of bed-time, led to more sleep and lower sleep latencies post-camp. Taken together, results suggest that incorporating sleep components into weight loss interventions may boost their influence on sleep and ultimately improve the effectiveness of treatment outcomes. Also, IT interventions for obese adolescents may have a modest effect on improving sleep; and hence, help address one the Healthy People 2020 sleep related goals to increase the number of adolescents who get sufficient sleep.[15]

A possible mechanism linking sleep to pediatric obesity is caloric intake. Results of a study of preschoolers in a weight loss intervention found that about an hour less of sleep per night was related to approximately 168 more calories consumed per day after the intervention.[8] Another study found that adolescents with shorter weekday sleep durations consumed more calories from fat, and were twice more likely to eat ≥475 calories in snacks.[16] Future research

could benefit from an additional focus on caloric intake as a potential mechanism linking sleep, weight status, and weight loss responsiveness.

While there were strengths to the present study, there were also several limitations. One limitation of the current study is the small sample size, particularly of the actigraph subsample, which limits the types of analyses, does not allow for the investigation and adjustment of possible confounders, and limits the conclusions that can be drawn. Also, generalizability of the sample must be taken into consideration as the sample consisted of mostly African-American female adolescents. Notably, African-American female adolescents have the highest rate of obesity among adolescents and African-American women have the highest rate of obesity among women.[17-18] Further, the primary sleep measures for the majority of the sample were subjective; particularly, the report of sleep durations may have been subject to recall bias. Future research should augment subjective measurements with more objective evaluations, such as actigraphy and polysomnography.

In conclusion, the current study results provide further evidence linking poor sleep patterns to pediatric obesity, and suggest that sleep patterns may impact the effectiveness of pediatric obesity interventions. This provides support for addressing sleep problems as part of obesity interventions. However, the current findings are preliminary, and there is a need for further research examining the influence of pre-treatment sleep patterns on the effectiveness of pediatric obesity interventions, and examining possible mechanisms, such as caloric intake.

Acknowledgements

The time of one of the authors (C.R.V.) for manuscript preparation was funded by NIHK01HL103155 from the National Heart, Lung, and Blood Institute, and the immersion treatment program and time of one of the other authors (D.N.C.) was supported, in part, by a grant from the Pitt County Memorial Hospital Foundation.

References

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the united states, 2011-2012. *JAMA*. 2014;311(8):806-814. Accessed 8/8/2014 2:57:22 PM.

2. Must A, Strauss RS. Risks and consequences of childhood and adolescent obesity. *Int J Obes*. 1999;23:S2-S11. Accessed 8/8/2014 4:03:34 PM. doi: 10.1038/sj/ijo/0800852.

3. Suchindran C, North KE, Popkin BM, Gordon-Larsen P. Association of adolescent obesity with risk of severe obesity in adulthood. *JAMA*. 2010;304(18):2042-2047. Accessed 8/8/2014 3:35:08 PM.

4. Kitzmann KM, Dalton III WT, Stanley CM, et al. Lifestyle interventions for youth who are overweight: A meta-analytic review. *Health Psychology*. 2010;29(1):91. Accessed 8/28/2014 3:58:58 PM.

5. Chen X, Beydoun MA, Wang Y. Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. *Obesity (Silver Spring, Md.)*. 2008;16(2):265-274. doi: 10.1038/oby.2007.63.

6. Graef, DM, Janicke, DM, McCrae, CS. Sleep patterns of a primarily obese sample of treatment-seeking children. *J Clin Sleep Med.* 2014; 10(10):1111-1117. doi: 10.5664/jcsm.4112.

7. Jarrin D, Mcgrath J, Drake C. Beyond sleep duration: Distinct sleep dimensions are associated with obesity in children and adolescents. *Sleep Med*. 2013;14:e159. Accessed 8/8/2014 6:01:21 PM. doi: 10.1016/j.sleep.2013.11.367.

8. Nugent R, Althouse A, Yaqub Y, Nugent K, Raj R. Modeling the relation between obesity and sleep parameters in children referred for dietary weight reduction intervention. *South Med J*. 2014;107(8):473-480. Accessed 8/28/2014 4:40:02 PM. doi: 10.14423/SMJ.0000000000000145 [doi].

9. Clifford LM, Beebe DW, Simon SL, et al. The association between sleep duration and weight in treatment-seeking preschoolers with obesity. *Sleep Med*. 2012;13(8):1102. doi: 10.1016/j.sleep.2012.06.019.

10. Carraway ME, Collier DN, Lutes LD, et al. Camp-based immersion treatment for obese, low socioeconomic status, multi-ethnic adolescents. *Childhood obesity (Print)*. 2014;10(2):122-131. Accessed 8/8/2014 6:01:21 PM. doi: 10.1089/chi.2013.0111.

11. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, et al. CDC growth charts: United States. Adv Data 2000 Jun; 8(314):1-27.

12. LeBourgeois MK, Giannotti F, Cortesi F, Wolfson AR, Harsh J. The relationship between reported sleep quality and sleep hygiene in italian and american adolescents. *Pediatrics*. 2005;115(1 Suppl):257-265. Accessed 8/8/2014 5:47:41 PM. doi: 10.1542/peds.2004-0815H.

13. Sadeh A, Sharkey KM, Carskadon MA. Activity-based sleep-wake identification: An empirical test of methodological issues. *Sleep*. 1994;17(3):201-7.

14. Carskadon, MA. Factors influencing sleep patterns of adolescents. (2002). In MA. Carskadon (Ed.), *Adolescent Sleep Patterns: Biological, Social, and Psychological Influences* (pp. 4-26). Cambridge: Cambridge University Press.

15. Sleep Health. Healthy People 2020 topics and objectives. Available at www.healthypeople.gov/2020/topicsobjectives2020?overwview.aspx?Topicid=38. Accessed September 3, 2014

16. Weiss A, Xu F, Storfer-Isser A, Thomas A, Ievers-Landis CE, Redline S. The association of sleep duration with adolescents' fat and carbohydrate consumption. *Sleep*. 2010; 33(9):1201-9.

17. Eaton DK, Kann L, Kinchen S, et al. Youth risk behavior surveillance - united states, 2011. *MMWR Surveill Summ*. 2012;61(4):1-162. Accessed 8/18/2014 11:12:31 AM. doi: ss6104a1 [pii].

18. National Center for Health Statistics (US. Special feature on emergency care. . 2013. Accessed 8/18/2014 11:34:45 AM; 8/18/2014 11:34:45 AM.

Table A. 1

Pre- and Post-Intervention Differences in Weight and Sleep Variables for Actigraph Subsample (n = 6)

	M_{pre}	SD_{pre}	M_{post}	SD_{post}	M_{diff}	*Cohen's d*
zBMI	2.28	0.44	2.13	0.53	.15	0.31[a]
Waist Circumference (cm)	100.2	9.29	98.2	10.83	2.0	0.20[a]
Total Sleep Time (hr:min)	7:56	1:05	8:12	1:08	-0:16	-0.25[a]
Sleep Efficiency (%)	93.68	5.01	94.57	5.34	-0.88	-0.17
Activity Index (%)	34.04	10.48	33.28	9.63	0.76	0.07
Sleep Latency (min)	7.88	4.10	6.21	1.97	1.67	0.52[b]

[a]small effect size; [b]medium effect size; [c]large effect size
Notes. All actigraphy variables are composites of sleep across 4-7 nights of sleep.